[Sorghum TechNote PRF 7-15]

# An assessment of three grain sorghums by ‘contour plots’

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## 1. Introduction

Nutritional geometry, as an equilateral triangular trial-design, was used to generate ‘contour plots’ or response surfaces to interpret variations in performance of broilers offered nutritionally equivalent diets based on three different grain sorghums, Block I, Liberty and HP. Steam-pelleted, basal diets were blended to constitute ten dietary treatments and were offered to male broiler chicks from 7 to 28 days post-hatch to determine parameters of growth performance and nutrition utilisation.

## 2. Materials and Methods

Three characterised sorghums with different protein, kafirin and phytate contents were used to formulate three nutritionally equivalent basal diets (Table 1). Liberty was a white sorghum and both Block I and HP were red. Following steam-pelleting at a conditioning temperature of 80°C, the three basal diets were proportionally mixed to form ten dietary treatments (Table 2) which filled the geometric space in an equilateral triangle as shown in Figure 1. Each of the ten dietary treatments was offered to six cages (6 birds per cage) or a total of 360 male Ross 308 chicks from 7 to 28 days post-hatch. Initial and final body weights were determined, feed intakes were recorded from which feed conversion ratios (FCR) were calculated. The incidence of dead or culled birds was recorded daily and their body-weights used to adjust FCR calculations. Total excreta collected from day 25-27 to generate data for parameters of nutrient utilisation [apparent metabolisable energy (AME); ME:GE ratios, N retention, N-corrected AME (AMEn)] on a dry matter basis.

**Table 1** Composition and nutrient specifications of sorghum-based experimental diets

| Item (g/kg) | Block I | Liberty | HP | Item (g/kg) | Block I | Liberty | HP |
|---|---|---|---|---|---|---|---|
| *Diet composition* | | | | *Calculated dietary nutrients* | | | |
| Sorghum | 620.0 | 620.0 | 620.0 | AME(MJ/kg) | 12.95 | 12.93 | 12.95 |
| Soybean meal | 224.6 | 225.4 | 230.0 | Protein | 217 | 186 | 187 |
| Canola meal | 75.0 | 75.0 | 75.0 | Starch | 378 | 388 | 388 |
| Sunflower oil | 28.0 | 24.0 | 20.0 | Calcium | 7.5 | 7.5 | 7.5 |
| Limestone | 7.4 | 6.9 | 6.9 | Phosphorus | 7.5 | 6.9 | 6.9 |
| Dicalcium phosphate | 16.5 | 16.1 | 16.1 | Phytate-phosphorus | 2.8 | 2.7 | 2.7 |
| Sodium chloride | 1.0 | 0.6 | 0.7 | Nonphytate phosphorus | 4.7 | 4.2 | 4.2 |
| Sodium bicarbonate | 4.5 | 4.9 | 4.9 | Sodium | 1.8 | 1.8 | 1.8 |
| Arginine | 0.5 | 1.3 | 1.1 | DEB | 208.0 | 207.7 | 211.0 |
| Isoleucine | - | 0.4 | 0.3 | | | | |
| Lysine | 2.5 | 3.5 | 3.3 | *Nutrients in sorghum* | | | |
| Methionine | 2.3 | 2.9 | 2.9 | Crude protein | 137.1 | 109.1 | 80.9 |
| Threonine | 0.7 | 1.3 | 1.2 | Kafirin | 67.1 | 41.4 | 50.5 |
| Valine | - | 0.7 | 0.6 | Phytate | 9.8 | 7.8 | 4.9 |
| Vitamin-mineral premix | 2.0 | 2.0 | 2.0 | | | | |
| Celite | 15.0 | 15.0 | 15.0 | | | | |

**Table 2** The proportions (%) of each basal diets in ten dietary treatments

| Treatment | Block I | HP | Liberty |
|---|---|---|---|
| 1A | 100 | 0 | 0 |
| 2B | 0 | 100 | 0 |
| 3C | 0 | 0 | 100 |
| 4D | 50 | 50 | 0 |
| 5E | 50 | 0 | 50 |
| 6F | 0 | 50 | 50 |
| 7G | 66.6 | 16.7 | 16.7 |
| 8H | 16.7 | 66.6 | 16.7 |
| 9I | 16.7 | 16.7 | 66.6 |
| 10J | 33.3 | 33.3 | 33.3 |

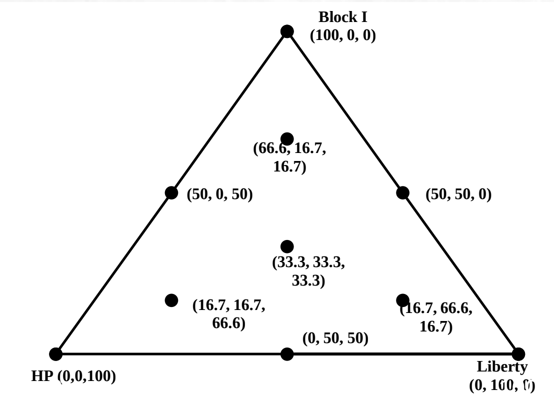


**Figure 1** Dietary treatments in an equilateral triangle design

## 3. Results and Discussion

The effects of dietary treatments on growth performance and nutrient utilisation are shown in Table 3 and weight gain, FCR, AMEn and ME:GE ratios will be given specific consideration. There were no significant treatment effects on weight gain, FCR and AMEn; however, there was a significant treatment effect ($P < 0.03$) on ME:GE ratios or, effectively, efficiency of energy utilisation. Diets based entirely on Liberty sorghum (Treatment 3C) had significantly higher ME:GE ratios ($P < 0.05$) than their counterparts based on Block I and HP sorghums (Treatments 1A, 2B).

**Table 3** Effects of dietary treatment on growth performance [WG, weight gain (g/bird); FI, feed intake (g/bird); FCR, feed conversion ratio (g/g)] and nutrient utilisation [AME, apparent metabolisable energy (MJ/kg); AMEn, nitrogen-corrected AME (MJ/kg); ME:GE, the ratio of metabolisable energy and gross energy (MJ/MJ); N retention, nitrogen retention (%)]

| Treatment | WG | FI | FCR | AME | AMEn | ME:GE | N retention |
|---|---|---|---|---|---|---|---|
| 1 | 1387 | 2301 | 1.660 | 13.38 | 11.87 | 0.800[a] | 68.22 |
| 2 | 1431 | 2334 | 1.631 | 13.26 | 11.85 | 0.800[a] | 68.36 |
| 3 | 1409 | 2342 | 1.663 | 13.47 | 12.14 | 0.827[c] | 72.39 |
| 4 | 1421 | 2334 | 1.664 | 13.39 | 11.81 | 0.802[a] | 72.01 |
| 5 | 1420 | 2343 | 1.650 | 13.46 | 12.00 | 0.814[abc] | 71.58 |
| 6 | 1441 | 2316 | 1.608 | 13.63 | 12.20 | 0.832[c] | 73.41 |
| 7 | 1359 | 2238 | 1.647 | 13.48 | 12.05 | 0.807[ab] | 70.11 |
| 8 | 1432 | 2313 | 1.615 | 13.52 | 12.03 | 0.816[abc] | 71.81 |
| 9 | 1432 | 2299 | 1.606 | 13.54 | 12.14 | 0.823[abc] | 71.40 |
| 10 | 1392 | 2261 | 1.626 | 13.37 | 11.90 | 0.811[abc] | 72.12 |
| SEM | 20.424 | 32.215 | 0.0183 | 0.1238 | 0.1103 | 0.0075 | 1.3775 |
| P-value | 0.139 | 0.318 | 0.142 | 0.673 | 0.158 | 0.029 | 0.156 |

Compared to conventional statistical designs, response surfaces generated by mixture designs are more sensitive in detecting significance of treatment effects. The relationship between weight gain and the proportions of three basal diets as shown in Figure 2a was predicted by the following equation ($r^2 = 0.99$, $P < 0.001$):

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$$WG = 13.792P_{BlockI} + 14.377P_{HP} + 14.173P_{Liberty} - 0.003158P_{BlockI}P_{HP} + 0.001309P_{BlockI}P_{Liberty} + 0.003499P_{HP}P_{Liberty}$$

Where $P_{BlockI}$, $P_{HP}$, $P_{Liberty}$ represents the percentage of diets based on sorghum Block I, HP and Liberty. Increasing the inclusion level of diet based on Block I compromised weight gain and the predicted optimal weight gain 1439 g/bird was achieved when the proportions of diets based on Block I, HP and Liberty were equal to 0.0%, 79.2% and 20.8%, respectively.

As shown in Figure 2b, the relationship between FCR and the three basal diet proportions was predicted by the following equation ($r^2 = 0.99$, $P < 0.001$):

$$FCR = 0.01655P_{BlockI} + 0.01631P_{HP} + 0.01651P_{Liberty} - 1.783 \times 10^{-5} P_{HP}P_{Liberty}$$

Similarly, higher inclusion rates of Block I compromised feed efficiency and the predicted optimal FCR 1.486 g/g was achieved when the proportions of diets based on Block I, HP and Liberty equal to 0.0%, 55.6% and 44.4%, respectively.

As shown in Figure 2c,the relationship between AMEn and the proportions of three basal diets was predicted by the following equation ($r^2 = 0.99$, $P < 0.001$):

$$AMEn = 0.01191P_{BlockI} + 0.1186P_{HP} + 0.1214P_{Liberty} - 1.927 \times 10^{-5} P_{BlockI}P_{HP} - 4.226 \times 10^{-6} P_{BlockI}P_{Liberty} + 7.799 \times 10^{-5} P_{HP}P_{Liberty}$$

Increasing the inclusion rates of diet based on Block I and HP compromised AMEn and the predicted optimal AMEn 12.38 MJ/kg was achieved when the proportions of diets based on Block I, HP and Liberty equal to 0.0%, 32.0% and 68.0%, respectively.

As shown in Figure 2d, the relationship between ME:GE and the proportions (%) of three basal diets was predicted by the following equation ($r^2 = 0.99$, $P < 0.001$):

$$ME{:}GE = 0.008P_{BlockI} + 0.008016P_{HP} + 0.008262P_{Liberty} + 6.520 \times 10^{-6} P_{HP}P_{Liberty}$$

Increasing the inclusion rates of diet based on Block I and HP would also compromise the ME:GE ratio. The predicted optimal ratio 0.845 MJ/MJ was achieved when the proportions of diets based on Block I, HP and Liberty equal to 0.0%, 31.1% and 68.9%, respectively.

All three sorghums did not contain condensed tannin on the basis of the Clorox bleach test; however, non-tannin phenolic compounds may possess anti-nutritive effects. Sorghum Block I had the highest kafirin and phytate concentrations and both factors in sorghum may contribute to inconsistent or sub-optimal growth performance in poultry. In the present study, increasing inclusions of Block I in experimental diets compromised weight gain, feed efficiency and energy utilisation. Both kafirin and phytate concentrations in the ten dietary treatments were negatively correlated to energy utilisation expressed as ME:GE ratios. The regression equation for the relationship between kafirin and ME:GE ($r = -0.437$; $P < 0.001$) is as follows:

$$y_{(ME:GE)} = 0.875 - 0.00179 * kafirin_{(g/kg)}$$

Similarly, the regression equation for the relationship between phytate and ME:GE ($r = -0.471$; $P < 0.001$) is as follows:

$$y_{(ME:GE)} = 0.866 - 0.007021 * phytate_{(g/kg)}$$

Both significant correlations suggest that increasing concentrations of kafirin and phytate in grain sorghum have a deleterious impact on energy utilisation of chickens offered sorghum-based diets. The relationships between kafirin and phytate with starch digestibility coefficients should prove highly instructive.

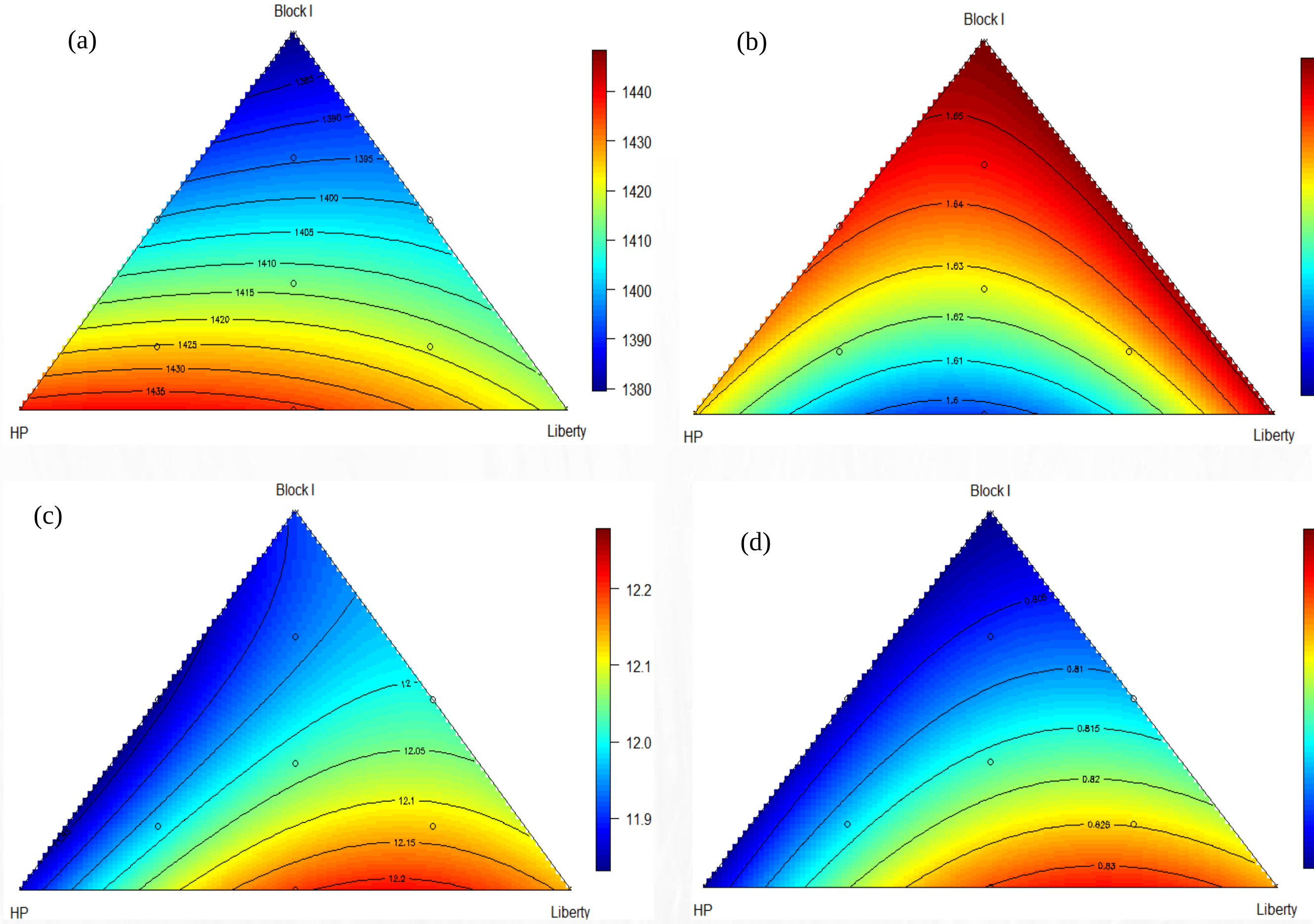


**Figure 2** Response surfaces of the relationships between the proportions of three basal diets and weight gain (a), feed conversion ratio (b), nitrogen-corrected apparent metabolisable energy (c) and the ratio of metabolisable energy and gross energy (d)

This TechNote was based on the following paper presented at APSS in February 2015.

Liu SY, Truong HH, Cadogan DJ, Selle PH (2015) "Contour plot' biometrics enhance interpretation of broiler bioassays. *Proceedings, Australian Poultry Science Symposium* **26**, (accepted for publication).